SLOT LINE TRANSITIONS

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THESIS

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by

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ABSTRACT

The slot line to coaxial line transition and the slot line to microstrip transition are investigated. Theoretical VSWR versus frequency curves for both transitions are computed and compared to experimental results. Techniques for measuring slot line VSWR are discussed.

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ACKNOWLEDGEMENT

The assistance and guidance provided by Professor J. B. Knorr is gratefully acknowledged. In addition to providing general guidance, Professor Knorr devised the computer programs used in calculating theoretical VSWR curves for the transitions investigated and constructed a slot line to microstrip transition which provided experimental data for this report.

I. INTRODUCTION

The slot line has been recently introduced by Cohn in Ref. 1 as another type of microwave transmission line. The slot line configuration, shown in Figure 1, consists of a narrow slot in the metal coating of a dielectric substrate. When the relative dielectric constant is approximately nine or greater, the electric and magnetic fields will be tightly bound to the region of the slot and energy will propagate down the slot.

Transitions from slot line to semi-rigid coaxial line and microstrip were proposed by Cohn [Ref. 1]. A report of tests performed on these transitions was presented by Robinson and Allen in Ref. 2. Models for these transitions were proposed by Chambers et al in Ref. 3.

The purpose of this thesis is to apply a theoretical analysis to transitions constructed in the laboratory and to compare the experimental and theoretical results. Because a measurement of the standing wave pattern along the slot is essential in experimentally evaluating a slot line transition, a portion of this thesis discusses the equipment used to make slot line VSWR measurements.

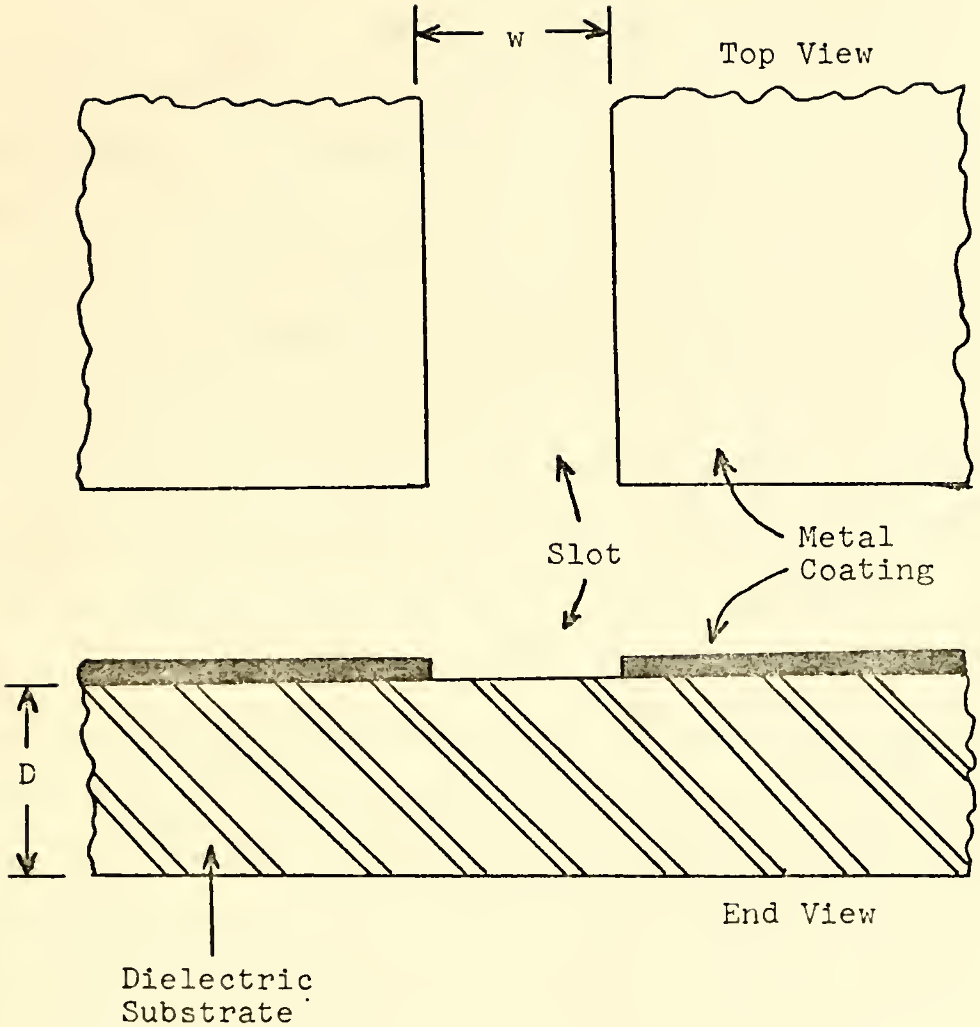


Figure 1. Slot line on a dielectric substrate.

II. SLOT LINE VSWR MEASUREMENTS

A slot line VSWR jig constructed by Jenners [Ref. 4] provided accurate measurements but did not allow for rapid positioning of the sensing probe, making data-taking a tedious process. In an attempt to improve the measurement technique, a Hewlett-Packard Model 809B Universal Probe Carriage was modified to accept slot line substrates. The modification, shown in Figure 2, consisted of suspending a frame of phenolic material two and one half inches below the carriage using the mounting holes which normally support the slotted wave guide section. The center section of the frame was left open to ensure the phenolic material did not interfere with slot line fields. Holes in the frame provided mounting for clamping screws to secure the substrate to the frame. The sensing probe was constructed by removing the inner probe section from the Hewlett-Packard 442B Broadband Probe Assembly and replacing it with .085 inch semi-rigid miniature coaxial line. The probe was oriented such that the inner conductor extended across the slot to sense the slot electric field. Some substrates were warped, causing the height of the probe above the slot to vary along the length of the slot. This change in probe height caused the VSWR meter readings to change from maximum to maximum and therefore made the VSWR measurements vary along the length of the slot. To minimize probe height changes along the

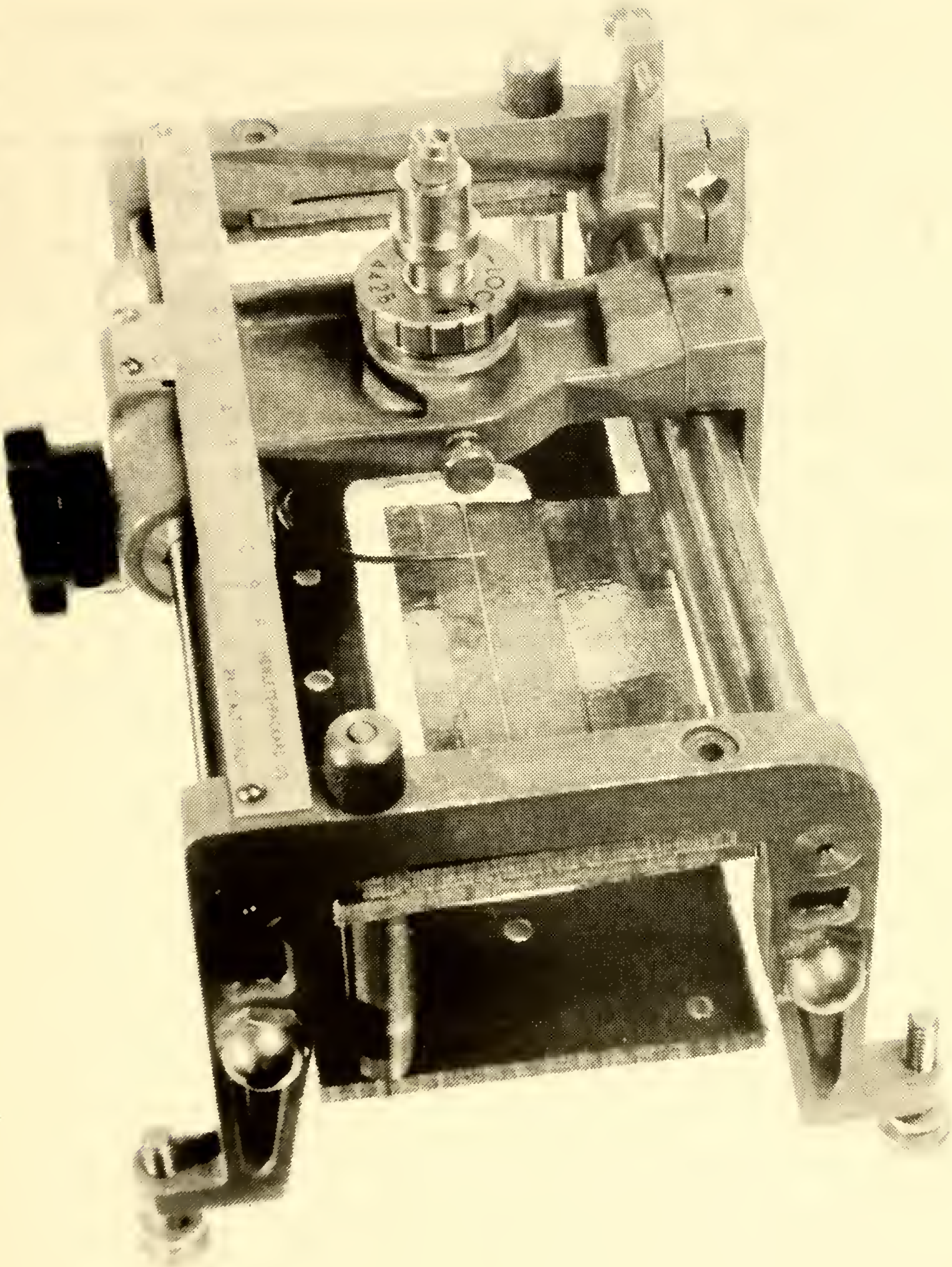


Figure 2. Probe carriage modified to accept slot line substrates.

length of the slot, the vertical height of the probe assembly was adjusted so that the outer conductor of the probe was just in contact with the metal coating of the substrate. Time domain reflectometry measurements made by Jenners [Ref. 4] indicated that coupling into the probe positioned with the outer conductor touching the metal was small and did not significantly disturb the slot fields.

The VSWR carriage described was used in making all of the slot line VSWR measurements made for this investigation. Measurements at frequencies below 4 GHZ were made with reasonable accuracy. At higher frequencies, the carriage was sufficient for measuring slot line wavelengths, but quantitative VSWR measurements became more uncertain due to minute fluctuations of the probe position relative to the slot.

III. SLOT LINE TO COAXIAL LINE TRANSITION

The slot line to coaxial line transition is shown in Figure 3. The actual configuration of the transition is too complex for analytical treatment. Therefore, the idealized model shown in Figure 4 was proposed by Chambers et al [Ref. 3] as a reasonable approximation for the transition. The model consists of a semicircular wire loop bridging the slot. A lumped load resistance equal to the coaxial line characteristic impedance Z_{co} is in series with the wire. The wire diameter d is equal to the diameter of the coaxial center conductor, and r is the effective loop radius approximately equal to the mean radial distance from the slot's center to the actual conductor path bridging the slot. The inductance of the semi-loop is in series with Z_{co}.

A. THEORETICAL VSWR

The inductance of a one-turn loop taking account of skin effect is given by Ref. 5 as:

$$(1) \qquad L_{loop} = 31.90\ r\ (\ln \frac{16r}{d} - 2)\ \text{nH}$$

where r and d are in inches. The inductance of the semi-loop is assumed to be half the one-turn loop. Therefore:

$$(2) \qquad L = 15.95\ r\ (\ln \frac{16r}{d} - 2)\ \text{nH}$$

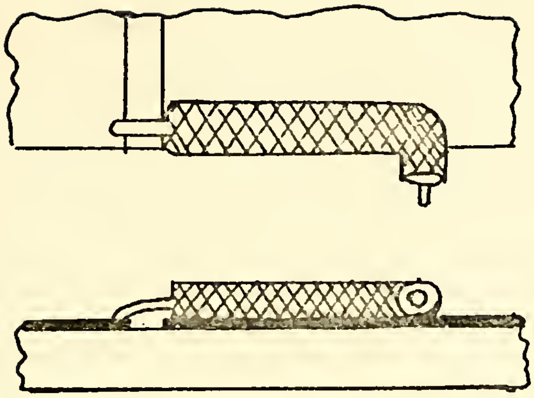


Figure 3. Slot line to coaxial line transition.

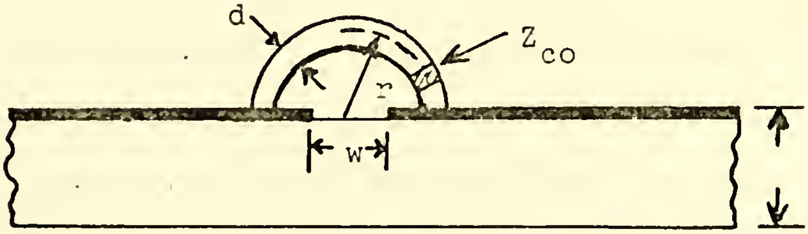


Figure 4. Simplified model for slot line to coaxial line transition.

The inductance of the actual transition configuration may be approximated by a judicious choice of r.

Assuming a slot line wave incident on the junction and the coaxial line terminated by its characteristic impedance, the voltage induced in series with the wire semi-loop is the line integral of the electric field at radius r in the absence of the wire. The resulting ratio n of voltage V(r) along the semicircular path at radius r to the voltage directly across the slot V_o is given by Ref. 1 as:

$$(3) \qquad n = \frac{V(r)}{V_o} = \frac{\pi}{2} \cdot |k_c r| \cdot |H_1^{(1)} (k_c r)|$$

where $k_c = j \frac{2\pi}{\lambda} \sqrt{(\frac{\lambda}{\lambda_s})^2 - 1}$ and $H_1^{(1)}(j|x|)$ is a Hankel function with an imaginary argument.

$\frac{\lambda_s}{\lambda}$ is the ratio of slot line wavelength to free space wavelength and is tabulated in Ref. 6 for various slot line parameters.

The induced voltage V(r) rather than the slot voltage V_o is impressed on the series combination of the load impedance Z_{co} and the inductive reactance $j\omega L$. Therefore, the equivalent circuit of the transition must contain an ideal transformer of turns ratio one to n between the slot line source and the coaxial line load. This turns ratio n is given by Equation (3) and is plotted in Figure 5.

Figure 6 shows the equivalent circuit of the transition. The shunt capacitance C represents the capacitance of the short length of slot line between the open end of the slot

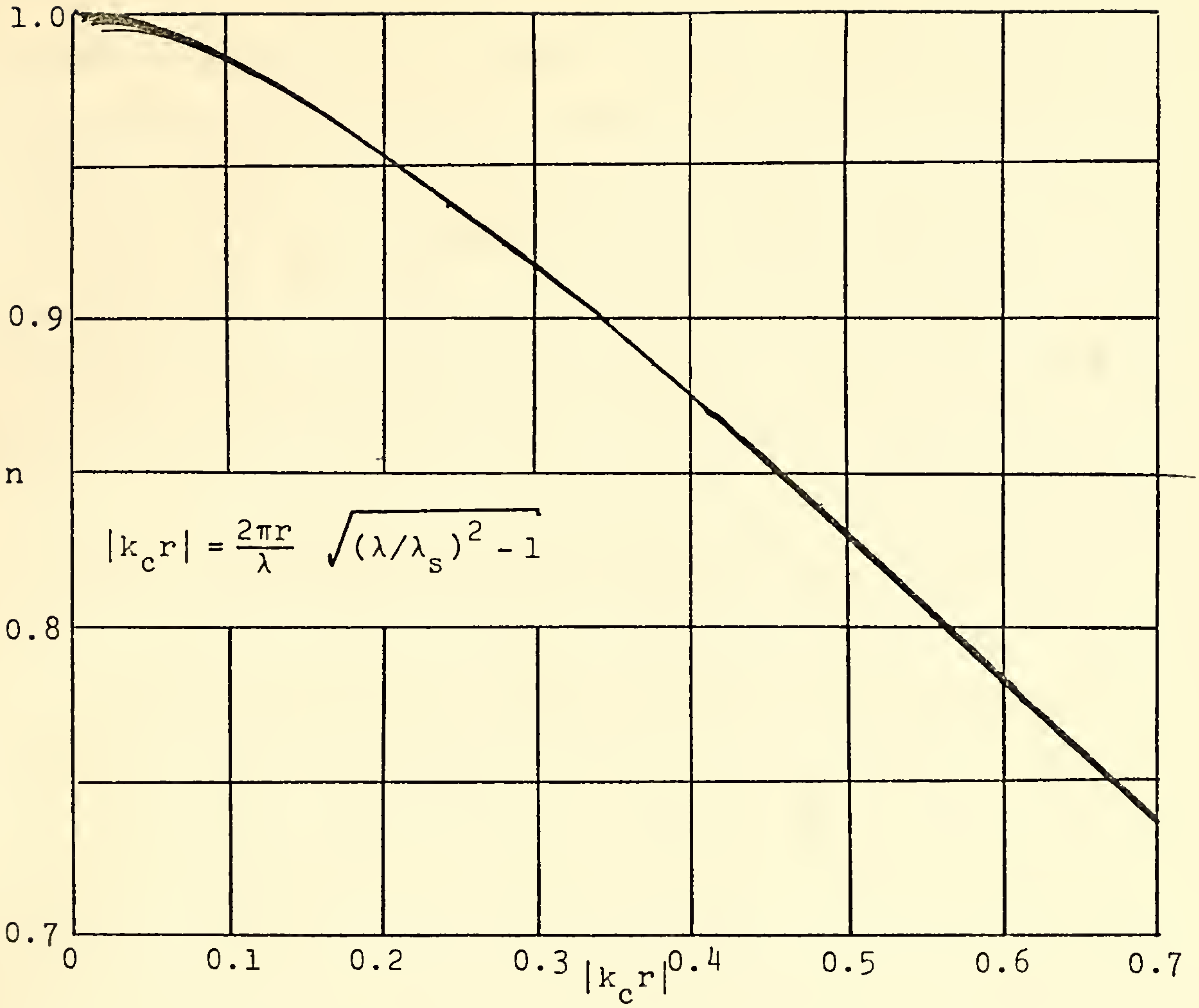


Figure 5. Transformer turns ratio for slot line to coaxial line equivalent circuit.

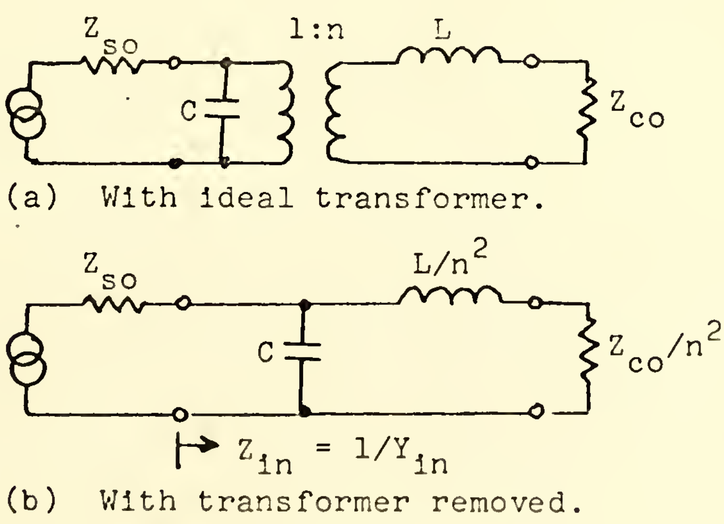


Figure 6. Equivalent circuit of slot line to coaxial line transition.

and the reference plane of the loop, plus fringing capacitance at the end of the slot. Typical values of C might range from 0.05 to 0.20 picofarads.

Z_{so} is the slot line characteristic impedance and is tabulated in Ref. 6 for various slot line parameters.

The input admittance of the transition seen by the slot line at the loop reference plane is obtained from Figure 6:

$$(4) \qquad Y_{in} = \frac{n^2 Z_{co}}{Z_{co}^2 + (\omega L)^2} - j\left[\frac{n^2 \omega L}{Z_{co}^2 + (\omega L)^2} - \omega C\right]$$

It can be determined from Equation (4) what the slot line characteristic impedance must be to match the fifty ohm coaxial line characteristic impedance at various frequencies. By shifting the position of the transition from the open-ended slot, the C may be chosen such that the imaginary part of Y_{in} is zero at a desired frequency in the operating band. Then at this frequency:

$$(5) \qquad Z_{in} = Z_{co} \left[\frac{1 + (\omega L/Z_{co})^2}{n^2}\right] + j0$$

Thus Z_{in}, the impedance which the slot line must match, has been increased compared to Z_{co} by the factor $[1/n^2]$ (greater than one) and the factor $[1 + (\omega L/Z_{co})^2]$.

The theoretical VSWR may be calculated using the relation:

$$(6) \qquad \text{VSWR} = \frac{1 + |k|}{1 - |k|}$$

where the reflection coefficient k is:

$$(7) \qquad k = \sqrt{\frac{(Y_{so} - \text{Re } Y_{in})^2 + (\text{Im } Y_{in})^2}{(Y_{xo} + \text{Re } Y_{in})^2 + (\text{Im } Y_{in})^2}}$$

B. COMPARISON OF THEORETICAL AND EXPERIMENTAL DATA

To compare the theoretical transition analysis with experimental data, a programmable calculator was employed to compute theoretical VSWR curves using the parameters of a slot line to coaxial line transition constructed and tested by Jenners [Ref. 4].

The slot line was constructed using a 0.117 inch thick substrate with a relative dielectric constant of 20. Metallization of the substrate was factory-applied copper. Slot width was 0.054 inches. The transition was constructed as shown in Figure 3 using 0.141 inch outer diameter semi-rigid coaxial line. VSWR measurements were made on the slot line with the coaxial line terminated with its characteristic impedance.

The effective radius used in the theoretical VSWR calculation was determined in two different ways and calculations made for each. In one method, the length of the semi-loop was assumed to be the width of the slot (0.054") plus half of the outer diameter of the semi-rigid coaxial line (0.0705"). The effective radius was therefore:

$$r = \frac{.054 + .0705}{\pi} = 0.0396''$$

The other method was to assume the effective radius equal to half of the outer diameter of the semi-rigid coaxial line:

$$r = 0.0705''$$

Using formula (2) with the diameter d of the inner conductor as .0359" gives:

$$L = 0.55 \text{ nH for } r = 0.0396''$$

$$L = 1.63 \text{ nH for } r = 0.0705''$$

For a given radius, there is a family of theoretical VSWR curves with C as the parameter. Curves were computed for C = .05, .10, .15 and .20 picofarads.

Figures 7 and 8 display the theoretical and experimental VSWR curves for the two choices of effective semi-loop radius. The theoretical curves calculated with an effective radius of 0.0396" agree more closely with the experimental curve.

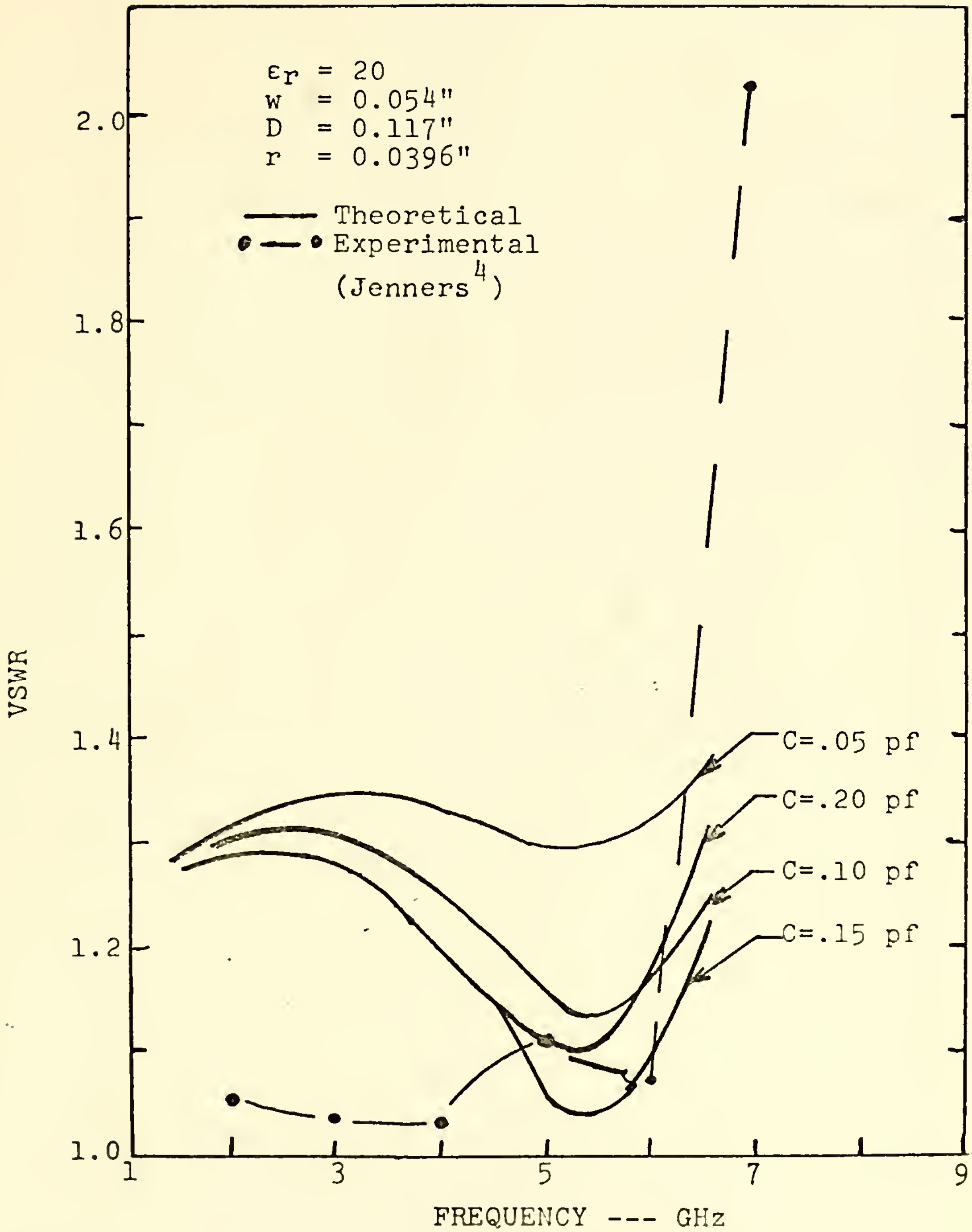


Figure 7. Experimental and theoretical values of VSWR for slot line to coaxial line transition.

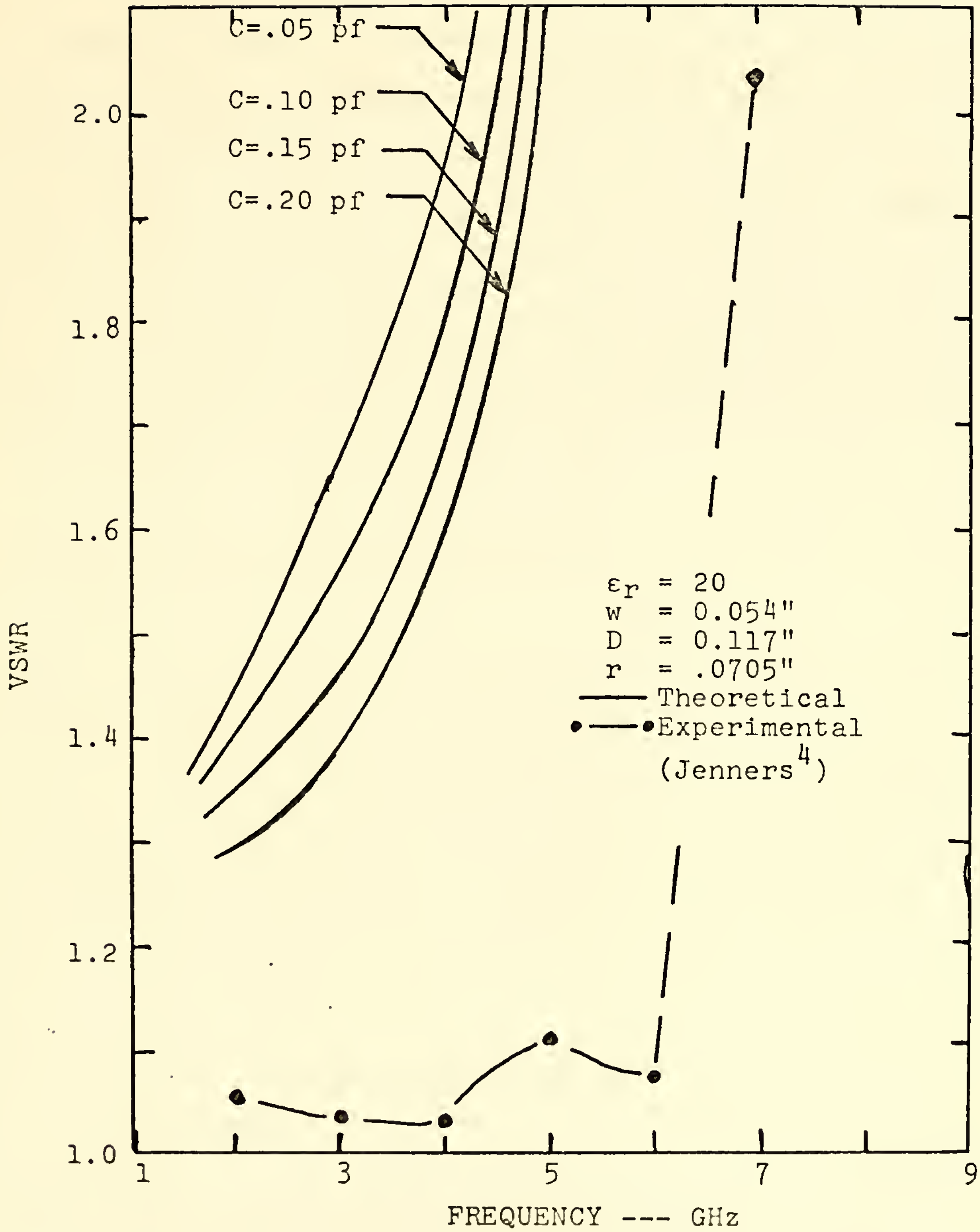


Figure 8. Experimental and theoretical values of VSWR for slot line to coaxial line transition.

IV. TERMINATION OF SLOT LINE WITH RESISTIVE LOAD

Another transition tested by Jenners was slot line terminated with a 50 ohm "pill" resistor as shown in Figure 9. The characteristics of this termination closely resemble the coaxial line termination and a similar theoretical analysis may be applied by changing the expression for the inductance of the semi-loop to reflect the change from a round to a flat conductor. The expression for the inductance of a loop of flat conductor is given by Ref. 7 as:

$$(8) \qquad L_{loop} = 0.004\, r\, [\ln 8r/b - \tfrac{1}{2}]\ \mu H$$

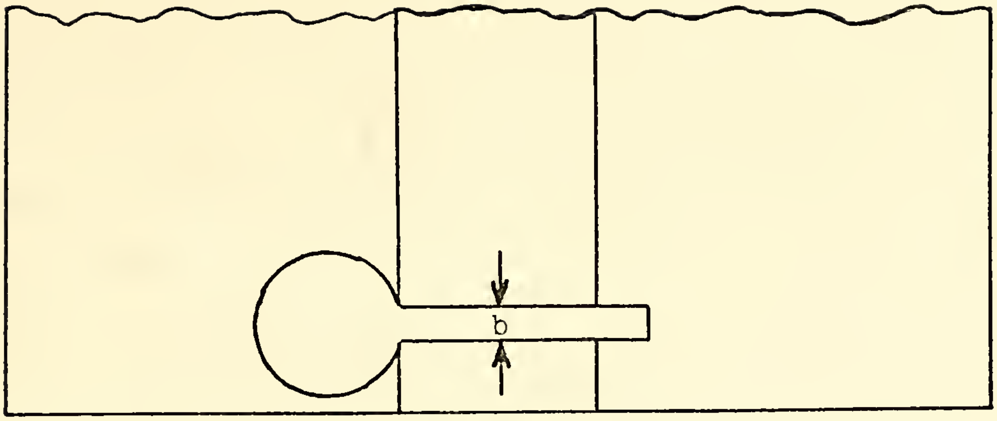
where r is the radius of the loop in centimeters and b is the width of the conductor in centimeters.

Assuming again that the inductance of the semi-loop is one half the inductance of the loop and converting the units from centimeters to inches, the inductance of the semi-loop is:

$$(9) \qquad L = 15.95\, r\, [\ln 8r/b - \tfrac{1}{2}]\ nH$$

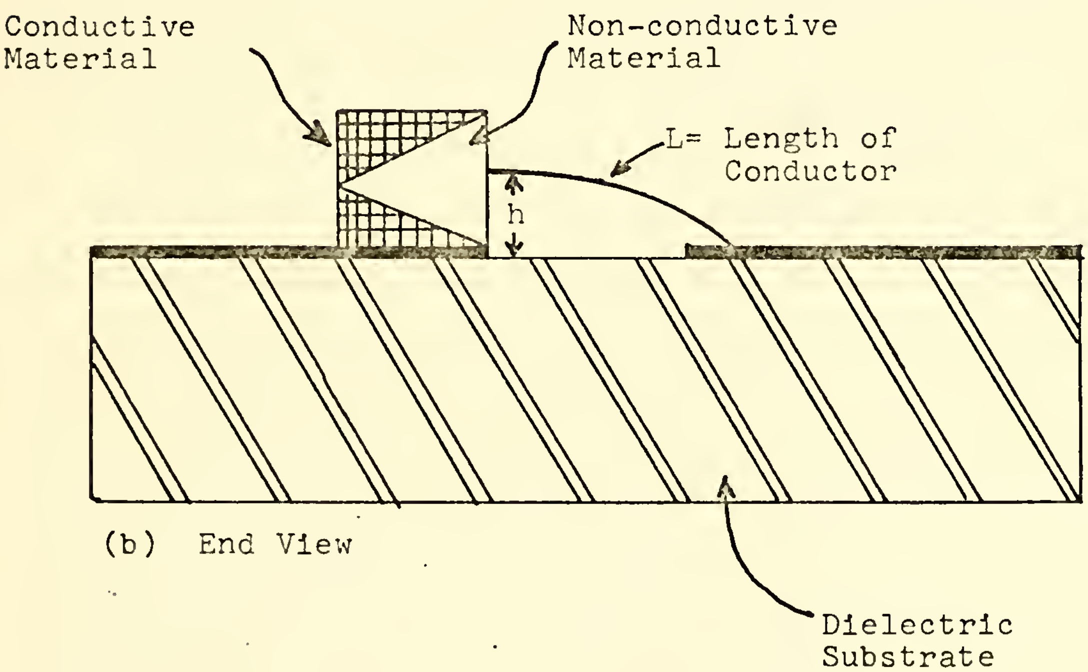
where r and b are expressed in inches.

For a conductor width of 0.060 inches, the semi-loop inductance for radii 0.040, 0.045 and 0.050 inches are 0.746, 0.927 and 1.105 nanohenries, respectively.



(a) Top View

b = .060"
H = .0625"
L = .11"



(b) End View

Figure 9. Termination of slot line with resistive load.

As with the coaxial line termination, the choice of the effective radius of the semi-loop is somewhat arbitrary. Assuming that the length of conducting surface making up the semi-loop is approximately one and one fourth times the length of the flat conductor, the effective radius is calculated as:

$$r = \frac{1.25\ (0.11")}{\pi} = 0.0437"$$

Because this value of r was only an approximation, theoretical VSWR curves were calculated for radii of 0.040, 0.045, and 0.050 inches.

A. COMPARISON OF THEORETICAL AND EXPERIMENTAL DATA

Reference 4 gives experimental VSWR data for terminations as shown in Figure 9 for two different values of slot line widths. The substrate used in both cases was 0.044 inch thick with a relative dielectric constant of 20. The metallization used was Circuit-Stik copper foil backed by an adhesive. Figures 10 through 15 display the theoretical and experimental VSWR curves for the three choices of semi-loop radius. Figures 10, 11 and 12 are for a slot width of 0.017". Figures 13, 14 and 15 are for a slot width of 0.031". As in the case of the slot line to coaxial line termination, there is a family of theoretical VSWR curves for a given radius with C as the parameter. Curves were computed for C = .05, .10, .15, .20 and .25 picofarads.

1. Compensation for Adhesive Effects

As reported by Mariani and Agrios in Ref. 8, the adhesive backing of the metal increases the slot line wavelength over the theoretical values predicted by Ref. 6. The increased slot line wavelength is due to the effective decrease of the relative dielectric constant of the substrate material caused by the presence of the adhesive in the region where the slot line fields are most intense.

In order to obtain the correct values of slot line characteristic impedance to use in the calculations of theoretical VSWR for the transitions investigated, it was necessary to compare the experimentally-obtained slot line wavelength curves supplied by Ref. 4 with the theoretical curves given by Ref. 6 to find a set of theoretical curves of a lower dielectric constant than that of the actual material used whose slot line wavelengths matched the experimental wavelength values. That set of theoretical curves can then be used to provide the correct theoretical values of slot line characteristic impedance. For the particular substrate under consideration, it was found that the adhesive reduced the relative dielectric constant from 20 to an effective value of 13.

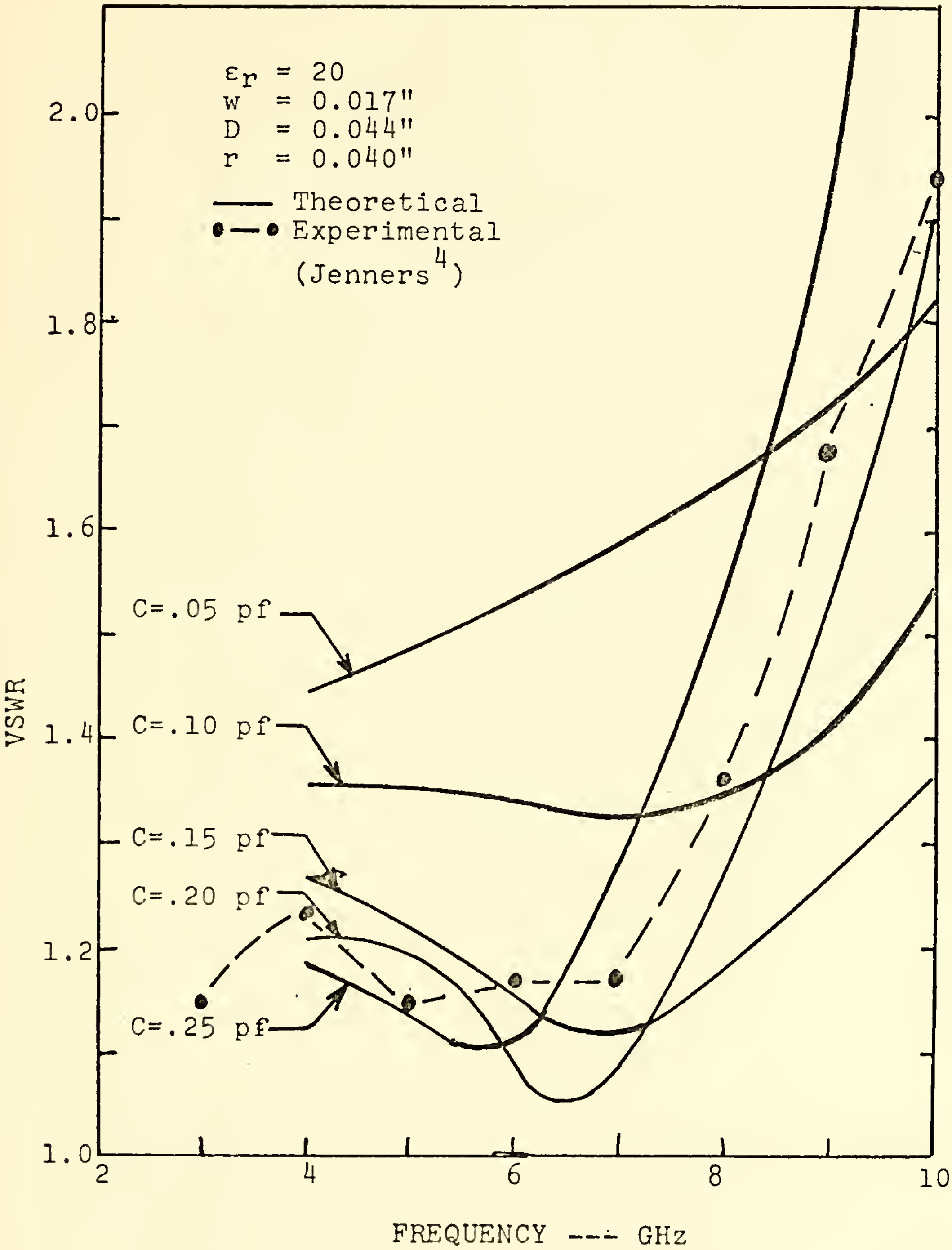


Figure 10. Experimental and theoretical values of VSWR for termination of slot line with resistive load.

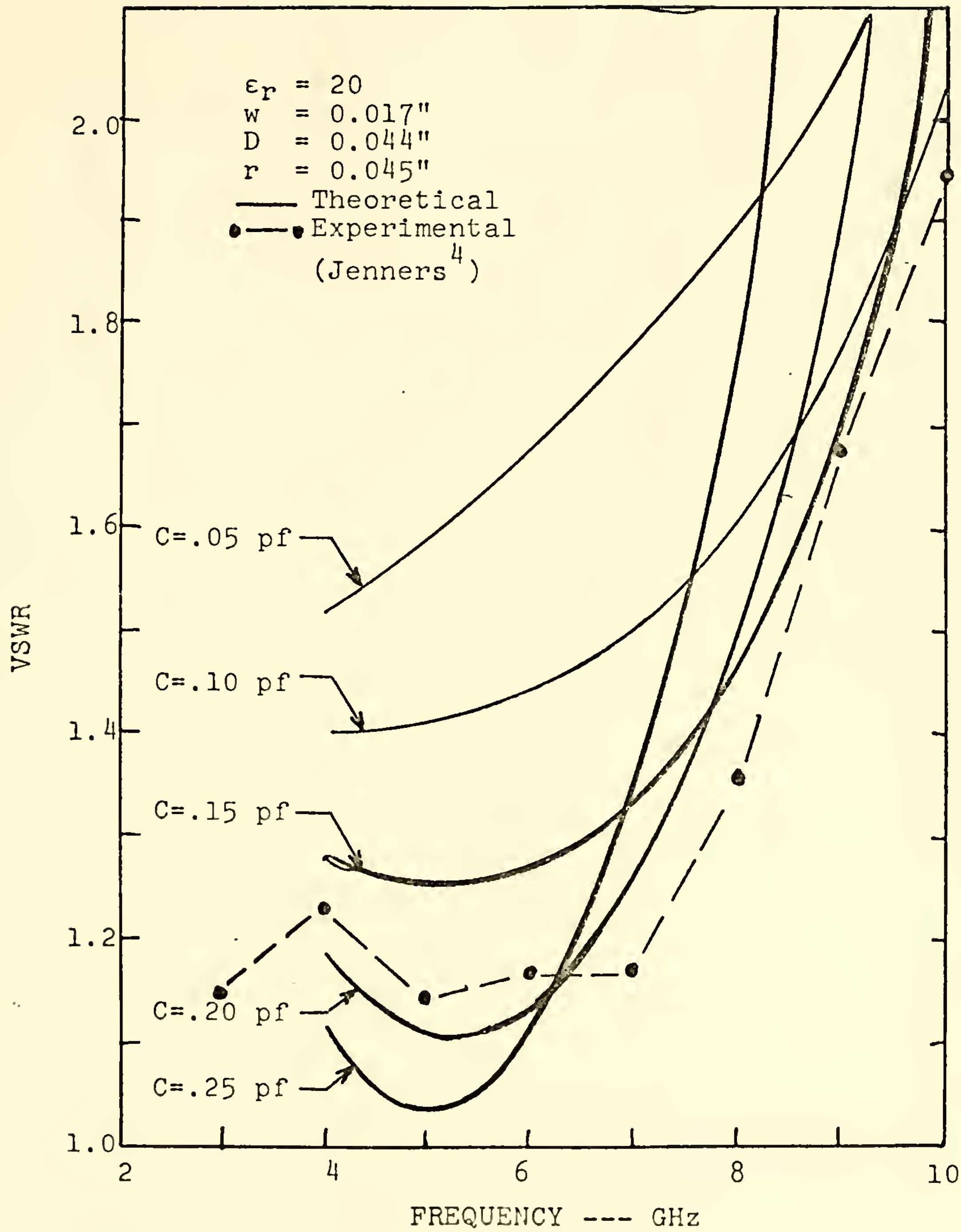


Figure 11. Experimental and theoretical values of VSWR for termination of slot line with resistive load.

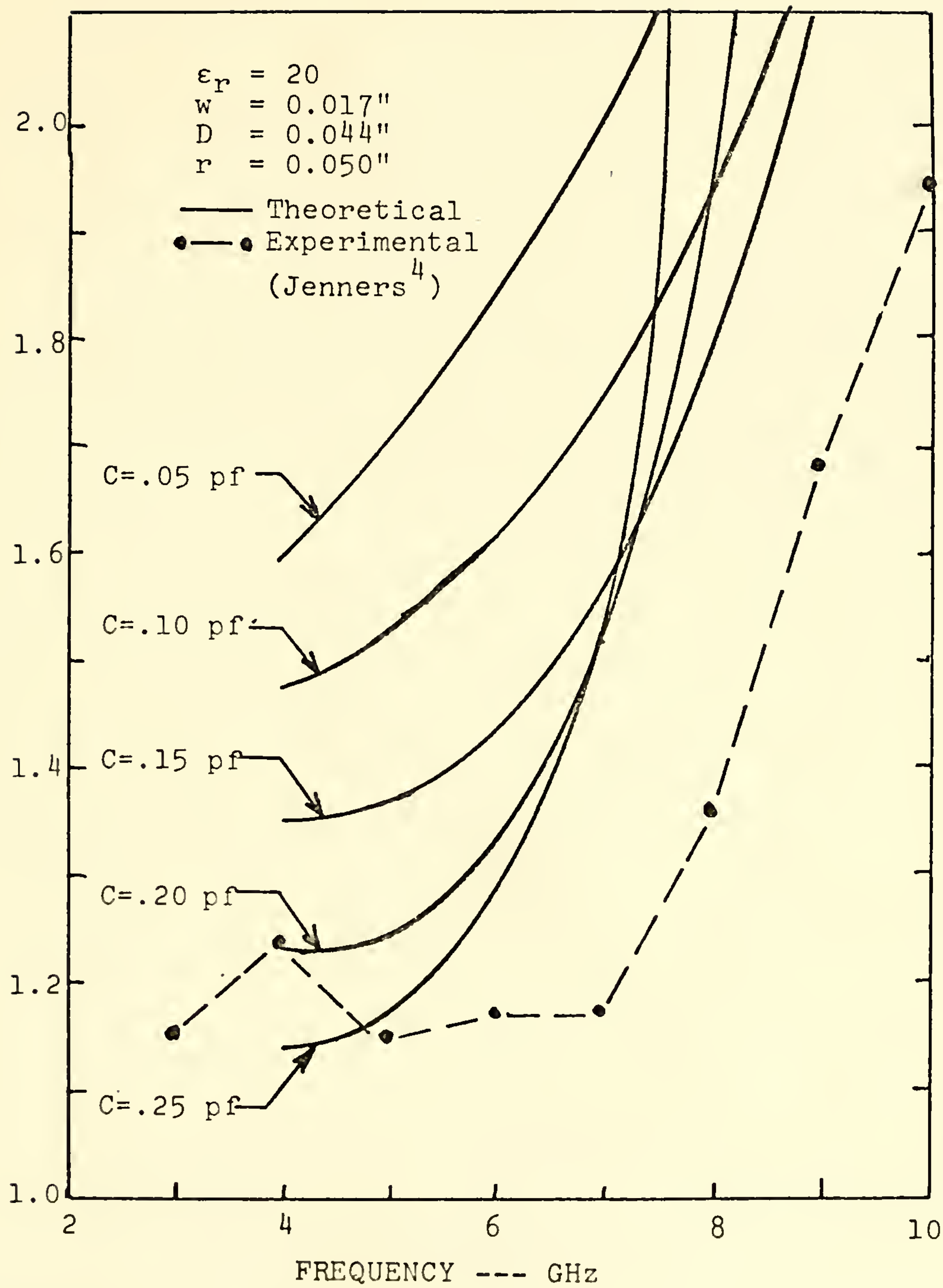


Figure 12. Experimental and theoretical values of VSWR for termination of slot line with resistive load.

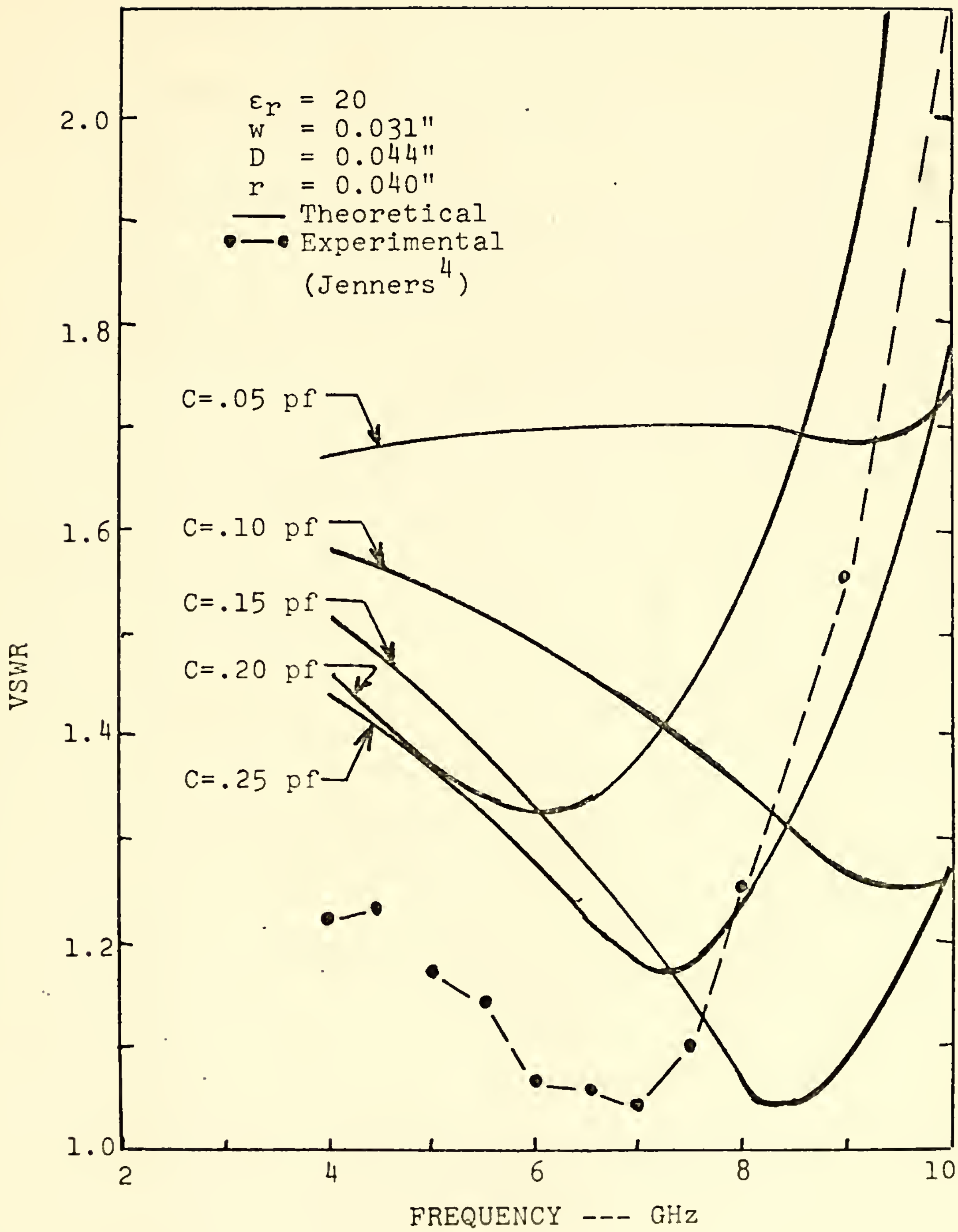


Figure 13. Experimental and theoretical values of VSWR for termination of slot line with resistive load.

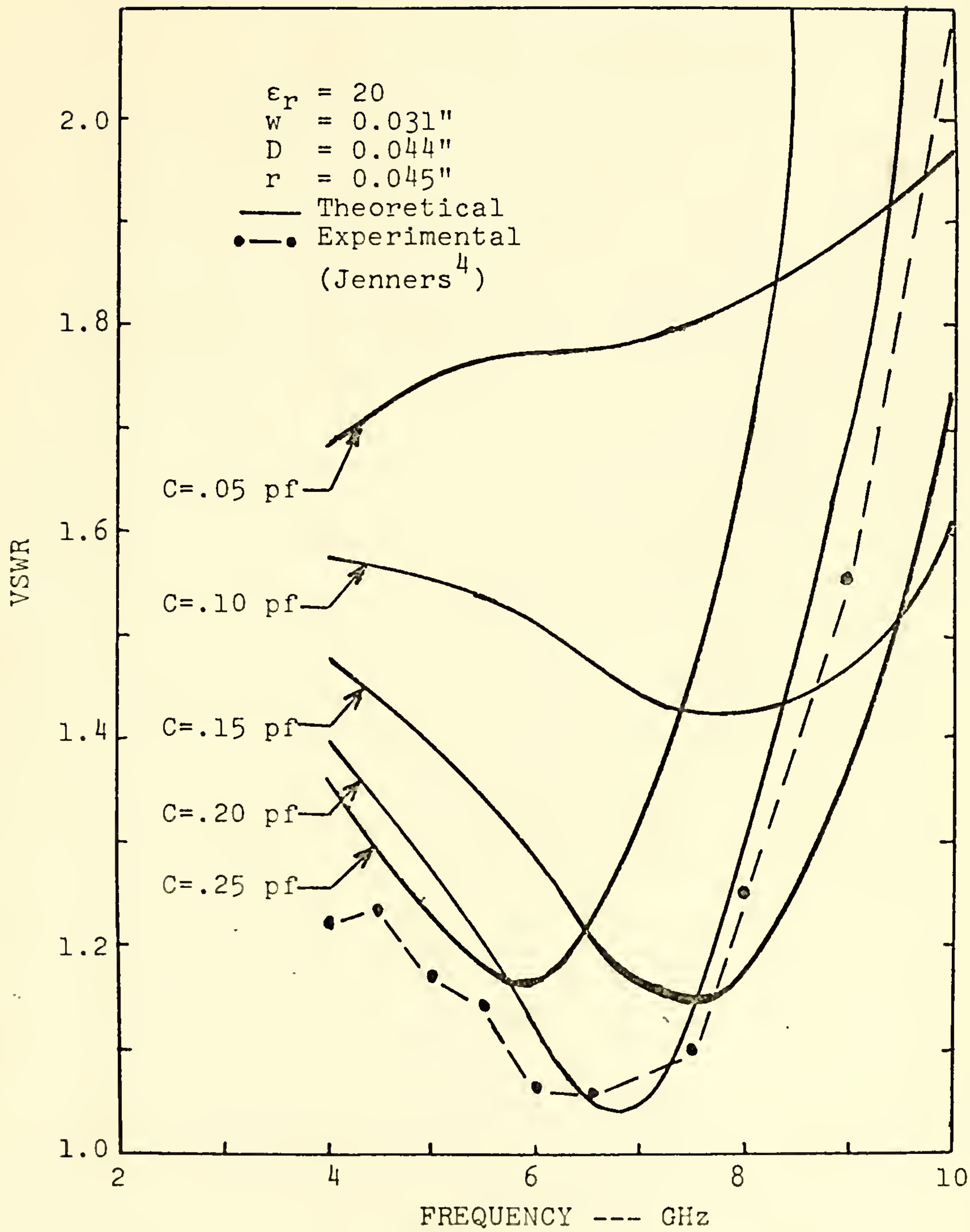


Figure 14. Experimental and theoretical values of VSWR for termination of slot line with resistive load.

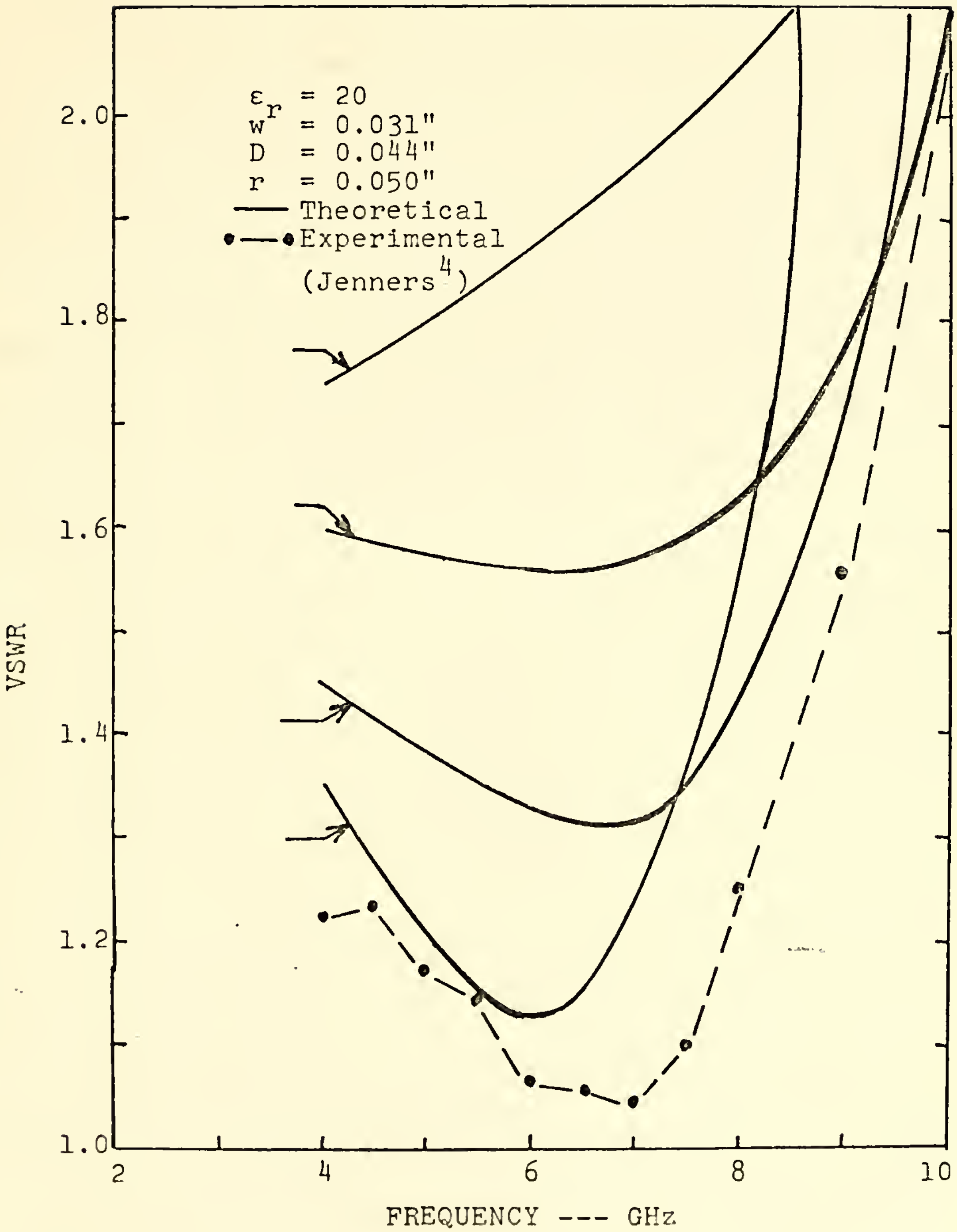


Figure 15. Experimental and theoretical values of VSWR for termination of slot line with resistive load.

V. SLOT LINE TO MICROSTRIP TRANSITION

The slot line to microstrip transition is shown in Figure 16. One side of the dielectric substrate is metallized and has a slot photo etched in it. The other side of the substrate has microstrip placed at right angles to the slot. Both the slot and the microstrip extend beyond the junction area for approximately one quarter wavelength at the center frequency of the transition. Because the microstrip and slot cross at right angles, coupling of the electromagnetic fields through the dielectric is tight.

A. THEORETICAL VSWR

Based on the equivalent circuit proposed by Chambers et al [Ref. 3] and shown in Figure 17, there follows a development of the equations necessary to calculate the theoretical VSWR of a slot line to microstrip transition. This development includes the inductive end effects of the short-circuited slot line as reported by Knorr and Saenz in Ref. 9 and the capacitive end effects of the open-circuited microstrip calculated by Silvester and Benedek in Ref. 10.

The quantities shown in Figures 16 and 17 and other necessary quantities are defined as follows:

Z_{so} - The characteristic impedance of the slot line.

Z_{mo} - The characteristic impedance of the microstrip.

Z_1 - The impedance presented at the junction point by the slot line quarter wave stub.

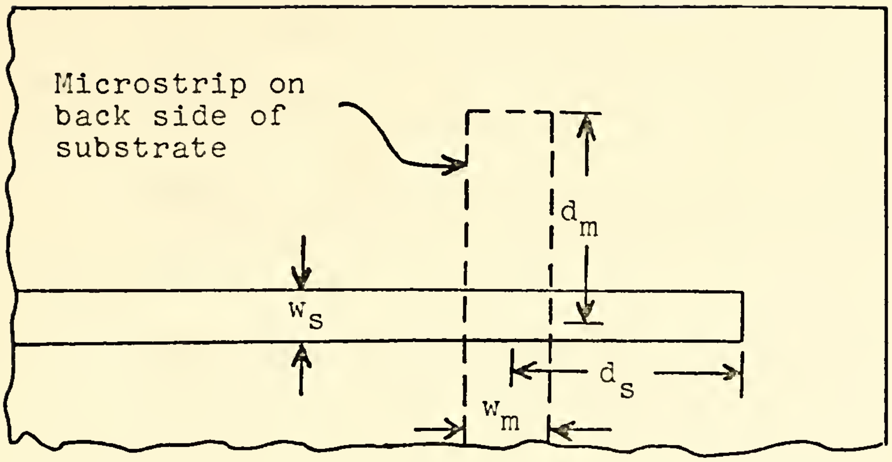
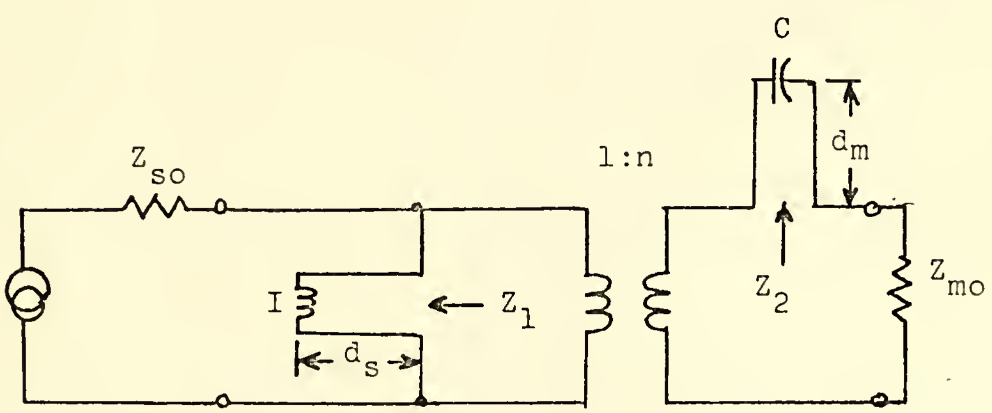
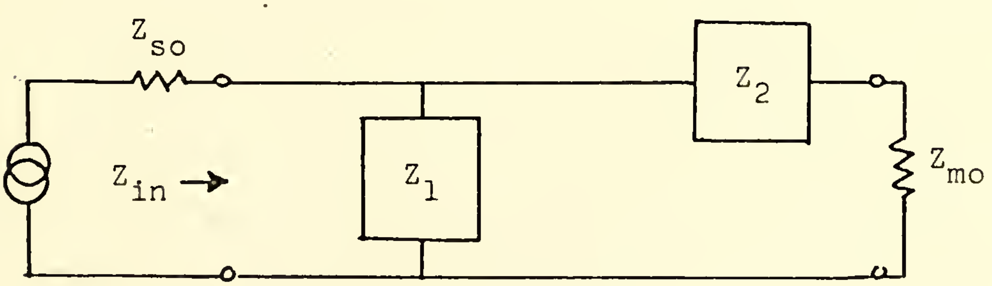


Figure 16. Slot line to microstrip transition.



(a) With ideal transformer.



(b) With transformer removed.

Figure 17. Slot line to microstrip transition equivalent circuit.

Z_2 - The impedance presented at the junction point by the microstrip quarter wave stub.

Z_{in} - The impedance seen by the slot line wave when incident on the junction.

L - The end effect inductance of the short-circuited quarter wave stub of slot line.

Y_L - The admittance of L.

C - The end effect capacitance of the open-circuited quarter wave stub of microstrip.

Y_C - The admittance of C.

w_s - Slot width.

w_m - Microstrip width.

d_s - Quarter wave slot line stub length.

d_m - Quarter wave microstrip stub length.

D - Substrate thickness.

ε_r - Relative dielectric constant of the substrate.

λ_s - Slot line wavelength.

λ_m - Microstrip wavelength.

n - Ideal transformer turns ratio.

1. Evaluation of Transformer Turns Ratio

Assuming a slot line wave incident on the junction, the turns ratio n as shown in the equivalent circuit is the ratio of the voltage induced in the microstrip to the voltage directly across the slot. The turns ratio n is given by Chambers et al [Ref. 3] as:

$$n = \cos \frac{2\pi Du}{\lambda} - \cot q \sin \frac{2\pi Du}{\lambda} \quad (10)$$

where

$$q = \frac{2\pi Du}{\lambda} + \tan^{-1}\frac{u}{v}$$

$$u = \sqrt{\varepsilon_r - (\lambda/\lambda_s)^2}$$

$$v = \sqrt{(\lambda/\lambda_s)^2 - 1}$$

2. <u>Evaluation of Junction Input Admittance</u>

From transmission line theory:

$$(11) \qquad Y_1 = 1/Z_1 = Y_{so}\left[\frac{Y_L + j\,Y_{so}\tan 2\pi d_s/\lambda_s}{Y_{so} + j\,Y_L\tan 2\pi d_s/\lambda_s}\right]$$

where

$$Y_{so} = 1/Z_{so}$$

Rearranging and using the trigonometric identity for $\tan(x + y)$, Equation (11) may be expressed as:

$$(12) \qquad Y_1 = j\,Y_{so}\tan\left[2\pi d_s/\lambda_s + \tan^{-1} Y_L/jY_{so}\right]$$

Similarly:

$$(13) \qquad Z_2 = 1/Y_2 = \frac{-j\,Z_{mo}}{\tan\left[2\pi d_m/\lambda_m + \tan^{-1} Y_c/jY_{mo}\right]}$$

Defining B_1 as the susceptance portion of Y_1 and X_2 as the reactance portion of Z_2:

$$(14) \qquad B_1 = Y_{so} \tan \left[2\pi d_s/\lambda_s + \tan^{-1} Y_L/jY_{so}\right]$$

$$(15) \qquad X_2 = \frac{-Z_{mo}}{\tan \left[2\pi d_m/\lambda_m + \tan^{-1} Y_C/jY_{mo}\right]}$$

By inspection of the equivalent circuit:

$$(16) \qquad \mathrm{Re}\, Y_{in} = n^2 \frac{Z_{mo}}{Z_{mo}^2 + X_2^2}$$

$$(17) \qquad \mathrm{Im}\, Y_{in} = B_1 - n^2 \frac{X_2}{Z_{mo}^2 + X_2^2}$$

The theoretical VSWR is calculated by inserting the expressions for the real and imaginary parts of the input admittance into Equations (6) and (7).

B. COMPARISON OF THEORETICAL AND EXPERIMENTAL DATA

To evaluate the validity of the foregoing theoretical analysis, two slot line to microstrip transitions were constructed and tested and the results compared to theory. The first transition was constructed by the author using substrate metallized with copper tape. The second transition was constructed by J. B. Knorr from dielectric material with factory-applied copper on both sides. The two transitions are discussed separately.

1. Transition Constructed With Copper Tape

The transition was constructed as shown in Figure 16 with the dielectric metallized with 3M copper tape backed by a conductive adhesive and the slot and microstrip photo-etched from the metal. The microstrip was terminated in a miniature coaxial connector fixed to the edge of the substrate. The slot was excited by a similar transition which was not experimentally evaluated.

a. Compensation for Adhesive Effects

As discussed in Section IV, the adhesive backing of the metallization results in a lowering of the effective dielectric constant. To ensure correct parameter values for the theoretical calculations, a measurement of the slot line wavelengths for the frequencies of interest was performed and compared to the theoretical curves of Ref. 3 in the same manner as described in Section IV. As indicated in Figure 18, the experimental curve of normalized slot line wavelength fell between the theoretical curves for $\varepsilon_r = 9.6$ and $\varepsilon_r = 11.0$. Also shown in Figure 18 are the theoretical values of slot line characteristic impedance for $\varepsilon_r = 9.6$ and $\varepsilon_r = 11.0$. The characteristic impedance curve for the constructed slot was assumed to lie between these two curves.

b. Parameters for Theoretical Calculations

The microstrip width was calculated to yield a microstrip characteristic impedance of 50 ohms using design curves from Ref. 11. Ref. 11 also supplied the theoretical microstrip wavelength. The values for λ_s/λ and Z_{so} were

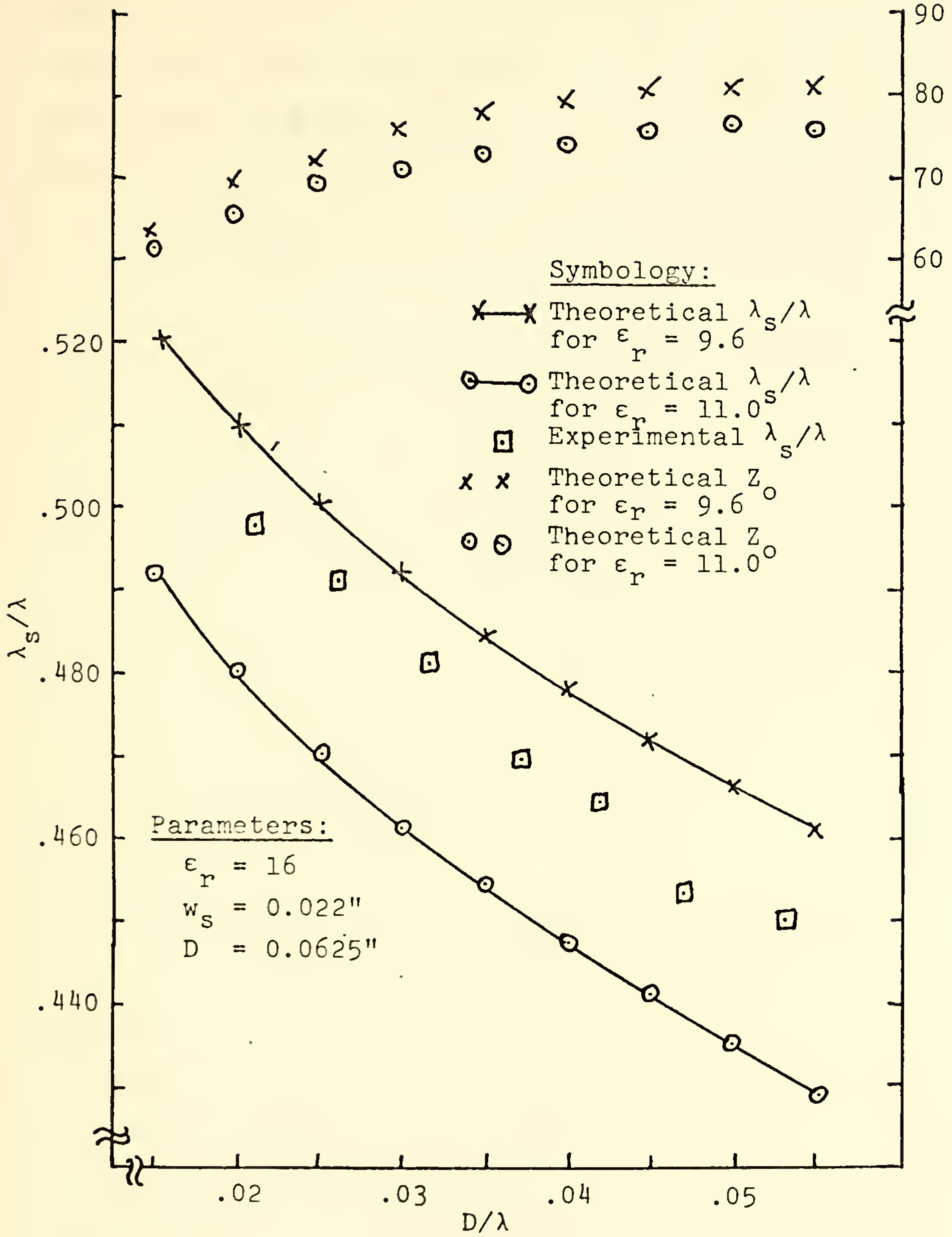


Figure 18. Theoretical and experimental values of λ_s/λ and theoretical values of Z_o for substrate metallized with adhesive-backed copper tape.

obtained from Figure 18. The inductive reactance for the short-circuited slot line stub was determined from the experimental data given in Ref. 9. The capacitance of the open-circuited microstrip stub was supplied by Ref. 10. Other pertinent transition parameters are listed below:

Center frequency	- 5 GHZ
D	- 0.0625"
Z_{mo}	- 50 ohms
λ/λ_m	- 3.2
d_m	- 0.184"
d_s	- 0.284"
w_s	- 0.022"
w_m	- 0.037"
C	- 94.0 pf
ε_r dielectric	- 16
ε_r effective	- 10.2

c. Theoretical and Experimental Comparisons

Computation of a theoretical VSWR versus frequency curve for the transition was made with the aid of a programmable calculator. A plot of the theoretical and experimental VSWR values is shown in Figure 19. While there is general agreement between the two curves, the experimental VSWR was not as low as predicted. The discrepancy might have been due in part to effects of the adhesive not accounted for in the VSWR calculation.

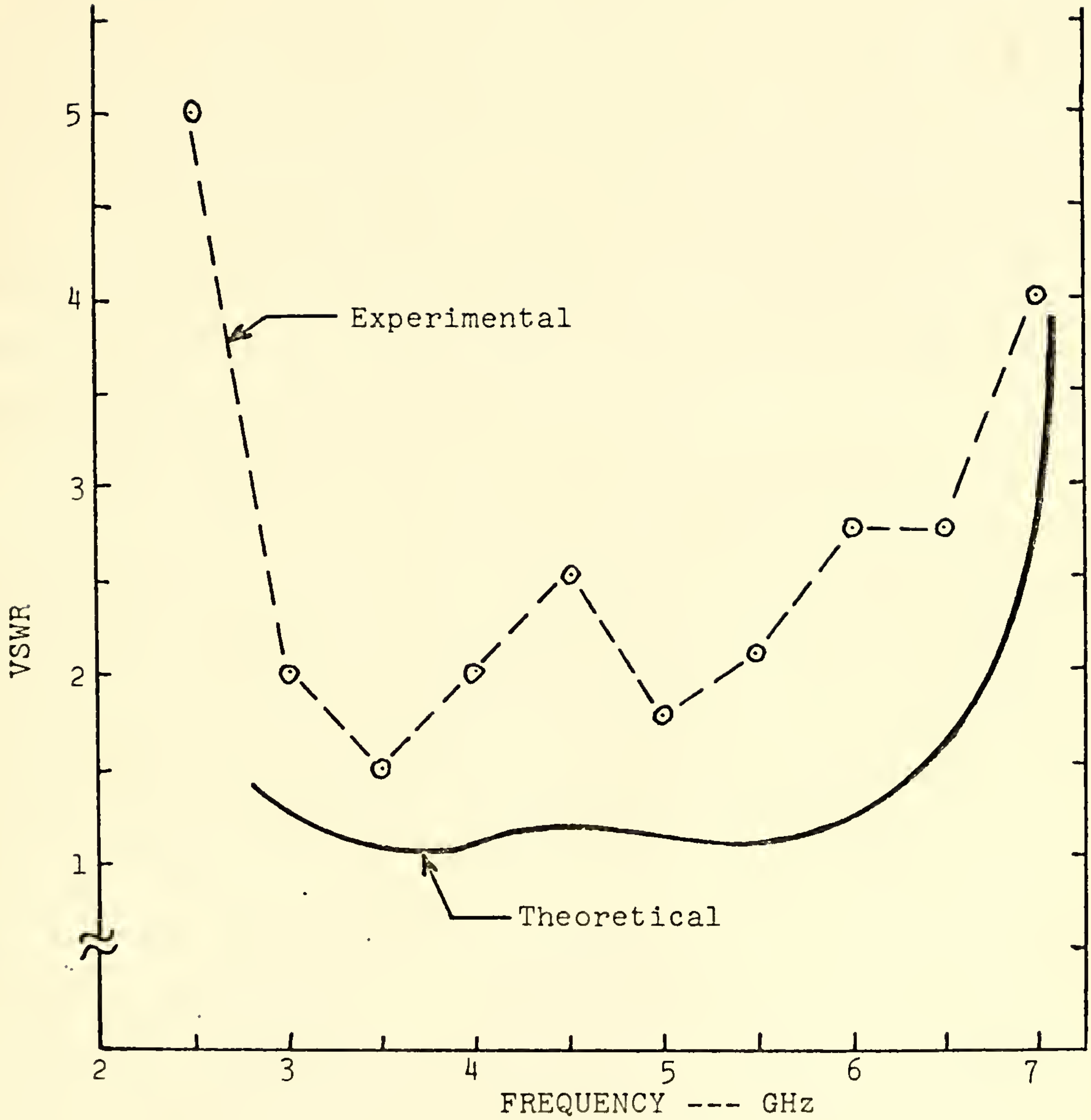


Figure 19. Experimental and theoretical values of VSWR for slot line to microstrip transition constructed with copper tape.

2. Transition Constructed With Factory-Applied Metal

The transition was constructed using substrate supplied with metal on both sides. Transition parameters that would optimize the VSWR of the transition at its center frequency were determined by the use of the computer program written to calculate the theoretical VSWR. The photo-etching process was employed to form the slot and microstrip. The microstrip was terminated with a miniature coaxial connector fixed to the edge of the substrate. The slot was excited by a slot line to coaxial line transition constructed as shown in Figure 3.

a. Parameters for Theoretical Calculations

The microstrip width and wavelength, the inductive reactance for the slot line stub and the capacitance of the open-circuited microstrip were obtained in the same manner as with the copper tape transition. λ_s/λ and Z_{so} were obtained directly from the theoretical curves of Ref. 3. Other pertinent parameters are listed below:

Center Frequency	- 3 GHz
Z_{mo}	- 50 ohms
λ/λ_m	- 3.5
d_m	- .255"
d_s	- .275"
D	- .125"
w_s	- .075"
w_m	- .057"

C - .153 pf

ε_r - 20

b. Theoretical and Experimental Comparisons

The VSWR of the transition was determined by terminating the microstrip in its characteristic impedance and exciting the slot through the coaxial line to slot line transition. VSWR measurements were then taken along the slot using the modified VSWR carriage. A comparison of the experimental and theoretical VSWR values is shown in Figure 20.

The transition VSWR was determined in a second manner by terminating the slot in its characteristic impedance and using a standard slotted coaxial line VSWR measurement carriage to measure the VSWR looking into the transition. The VSWR versus frequency plot obtained from this method was virtually the same as that shown in Figure 20.

The slot was terminated in its characteristic impedance by removing the slot line to coaxial line transition from the opposite end of the slot and replacing it with a 75 ohm chip resistor mounted directly in the slot. Because the slot width was such that the characteristic impedance of the slot was 75 to 80 ohms over the frequency range of interest, the chip resistor provided an effectively flat termination for the slot for the 2 to 5.5 GHz frequency range. This was verified by exciting the slot with the microstrip

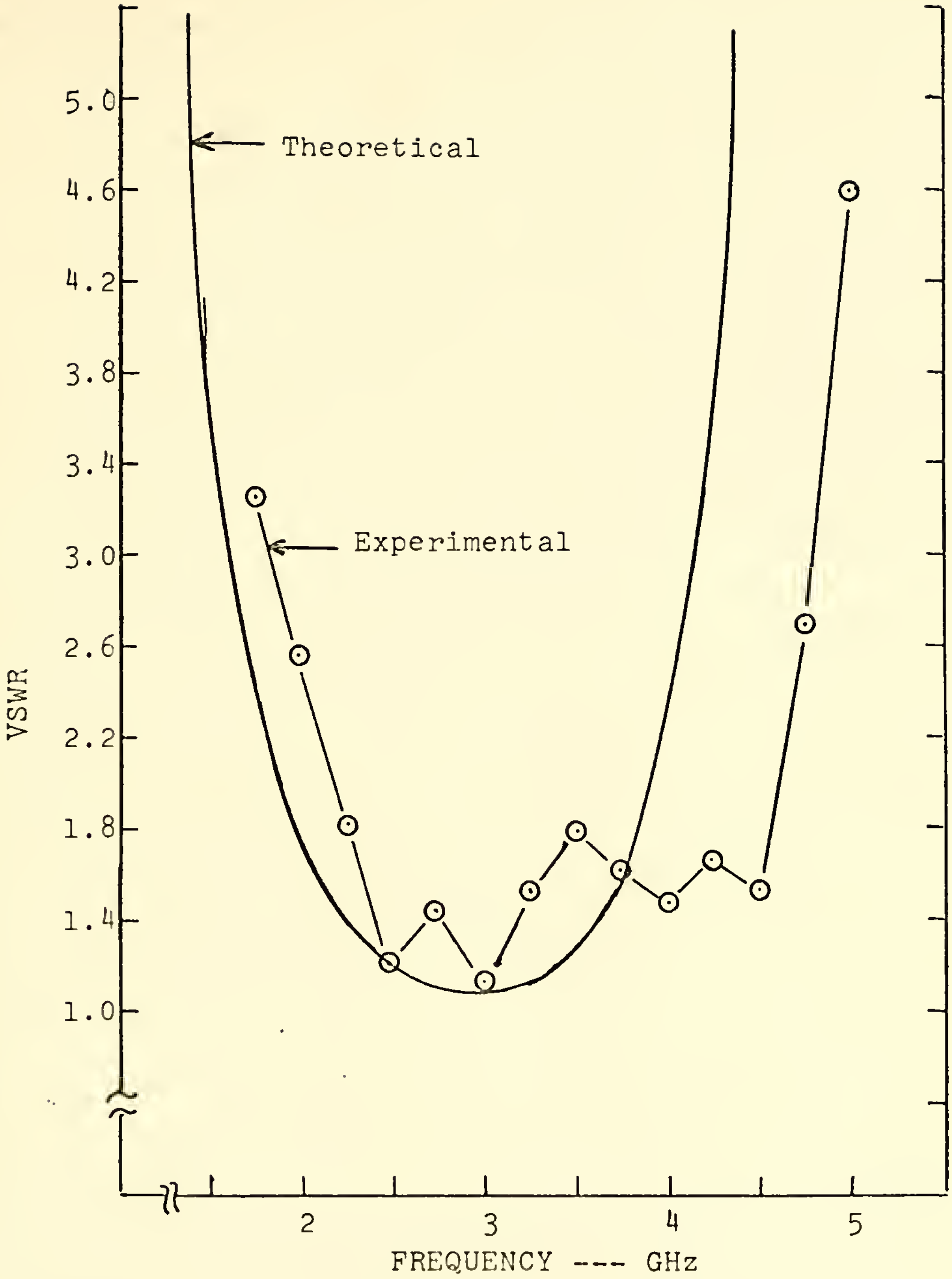


Figure 20. Experimental and theoretical values of VSWR for slot line to microstrip transition constructed with factory-applied metal.

transition and taking VSWR measurements along the slot. The measurement is shown in Figure 21.

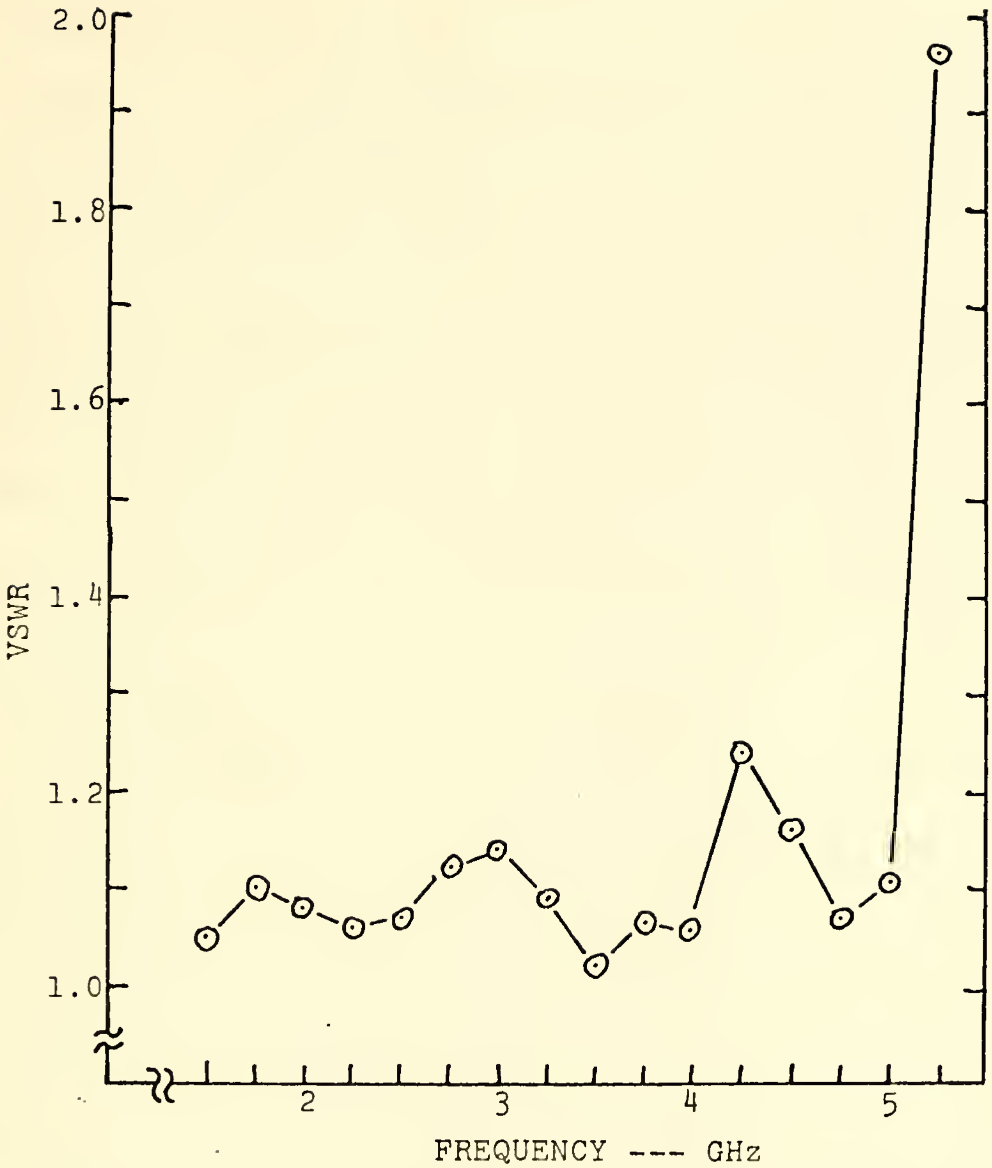


Figure 21. Experimental VSWR of slot line terminated with 75 ohm resistive chip.

VI. CONCLUSIONS

A. VSWR MEASUREMENTS

While the VSWR jig constructed by Jenners [Ref. 4] and the modified VSWR carriage described in Section I both provided useful VSWR measurement data, the accuracy of both deteriorated at higher frequencies. To provide stable VSWR measurements above 5 GHz, it will be necessary to devise a carriage which can maintain the sensing probe at exactly the same relative position with respect to the slot throughout the length of the slot. The carriage must also be able to accept a variety of sizes of substrates.

B. SLOT LINE TO COAXIAL LINE TRANSITION

From the theoretical curves of Figures 7 and 8 and 10 through 15, it can be seen that the transition may be optimized for a particular frequency range by adjusting r and C, the radius of the loop briding the slot and the capacitance of the open-ended slot. Physically, adjusting the radius is limited to small adjustments of the length and height above the slot of the coaxial line inner conductor that bridges the slot. The capacitance is changed by varying the distance of the transition from the slot's open end. It is difficult to correlate these physical adjustments with the theoretical r and C parameters for several reasons. One is that the physical transition differs from the model from which the theoretical parameters are derived. Another is that the

fringing capacitance of an open-ended slot has not yet been examined. For these reasons, it is concluded that the theoretical analysis of the slot line to coaxial line transition requires modification to provide a better representation of the physical transition before it can be used to confidently predict the performance of a physical transition.

C. SLOT LINE TO MICROSTRIP TRANSITION

The slot line to microstrip transition analysis uses few approximations and provides a systematic approach to the selection of optimum parameters for transition construction. As can be seen from Figure 20, the experimental VSWR curve is in good agreement with the experimental curve. The slight upward shift in frequency of the experimental curve might be due to measuring the quarter wave stub lengths to the centers of the slot and microstrip rather than to the edge.

A big advantage of the slot line to microstrip transition over the slot line to coaxial line transition is that construction can be very precise using photo-etching techniques. This factor and the good frequency range of the slot line to microstrip transition make it the transition of choice, especially at higher frequencies where physical construction must be held to close tolerances.

D. ADHESIVE EFFECTS

The poor results obtained using substrate metallized with adhesive-backed copper tape leads to the conclusion

that experimental work requiring correlation with theory should be carried out using only substrate with factory-applied metal. The use of the adhesive-backed metallization requires corrections to theoretical values which are tedious and possible sources of inaccuracies.

E. RESISTIVE CHIP TERMINATIONS

The data displayed in Figure 21 indicates that mounting a chip resistor equal to the characteristic impedance of the slot line in the slot is an extremely effective method of terminating a slot line in its characteristic impedance. Because the chip is mounted in the slot directly against the substrate material and directly adjacent to the metal, the impedance presented to the slot is the resistance of the chip unaffected by any transformer action as is the case with coaxial line or microstrip transitions.

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13. ABSTRACT

The slot line to coaxial line transition and the slot line to microstrip transition are investigated. Theoretical VSWR versus frequency curves for both transitions are computed and compared to experimental results. Techniques for measuring slot line VSWR are discussed.

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